National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Materials, Processes and Manufacturing Department
Environmental Effects Group

ENHANCEMENTS IN PHOTON PRESSURE MEASUREMENTS USING A SOLAR SIMULATOR

Perry Gray

David Edwards, and Ralph Carruth

OUTLINE

- **Background**
- **Calculations**
- **Description of Apparatus**
- **Results**
- **Summary**
- **Future**

BACKGROUND

- **This Work Supports Solar Sail Mission Development Activities**
- **Nichols, Hull, and Lebedew**
  - **Torsion Balance**
  - **Poor Vacuum**
  - **Radiometric Uncertainty**
- **Technical Advances Provide Better Accuracy**

CALCULATIONS

- **The Total Force, F_T, on the Sample Is:**
- **F_T = (1 + R)(Constant)(A)(suns)**
- **Where R is the Sample Reflectance, A Is The Sample Area, and Suns Is The Number of Air Mass Zero Earth Suns**
- **The Constant Is 4.56 x 10^{-10} N/cm^2**
- **The Number of Suns for This Experiment is 2.51**

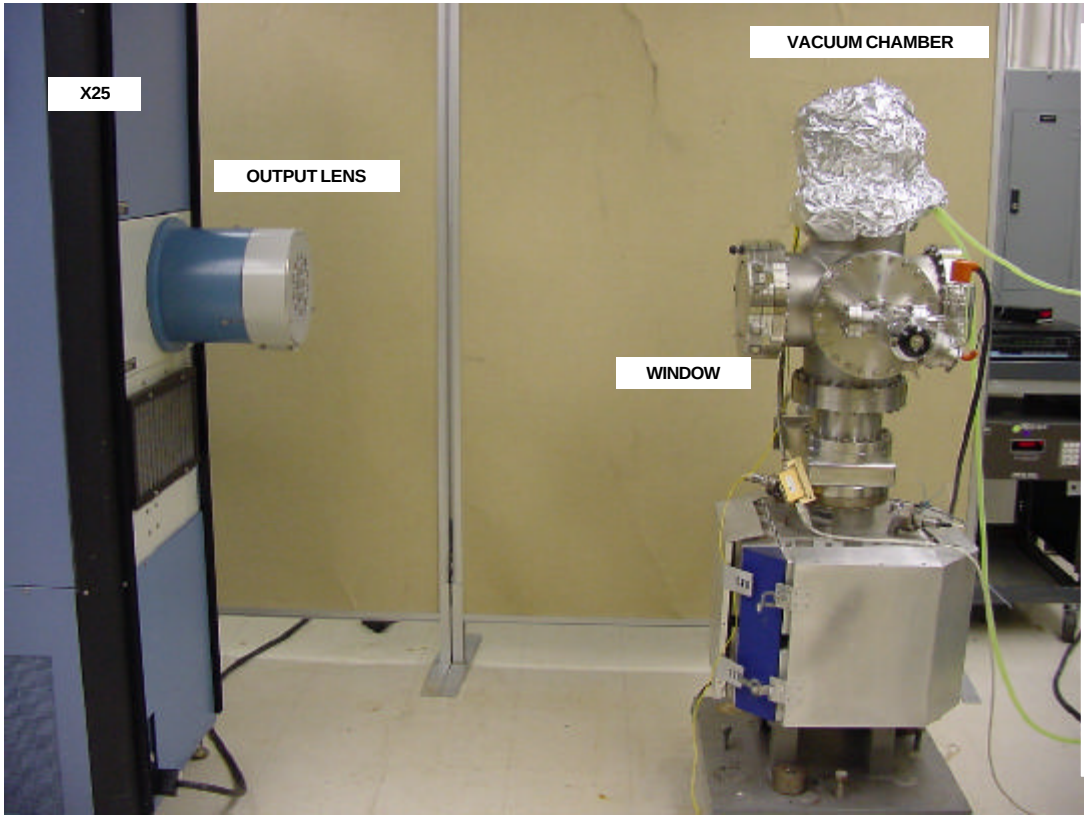
APPARATUS

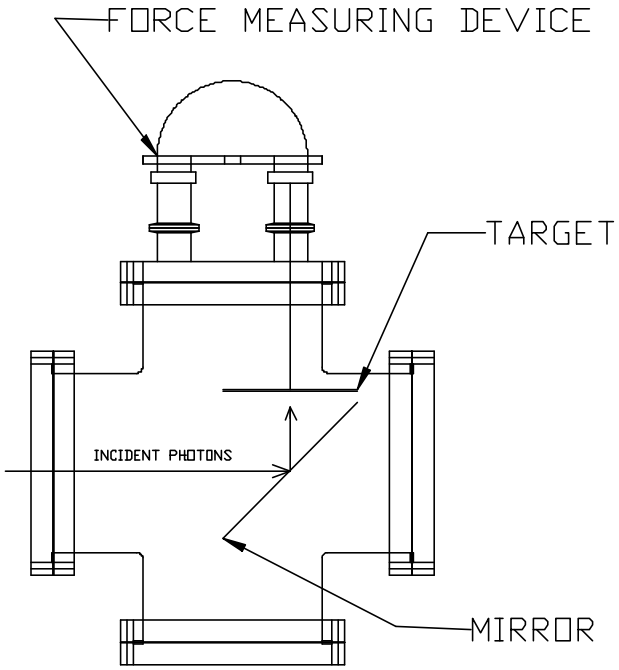
Solar Simulator

- **2500 W Xenon Arc Lamp**
- **Optics Produce Sun-like Spectrum**
- **Uniform 6 inch Diameter Beam**
- **2.5 Sun Beam**
- **Small Divergence Angle at Sample Plane**

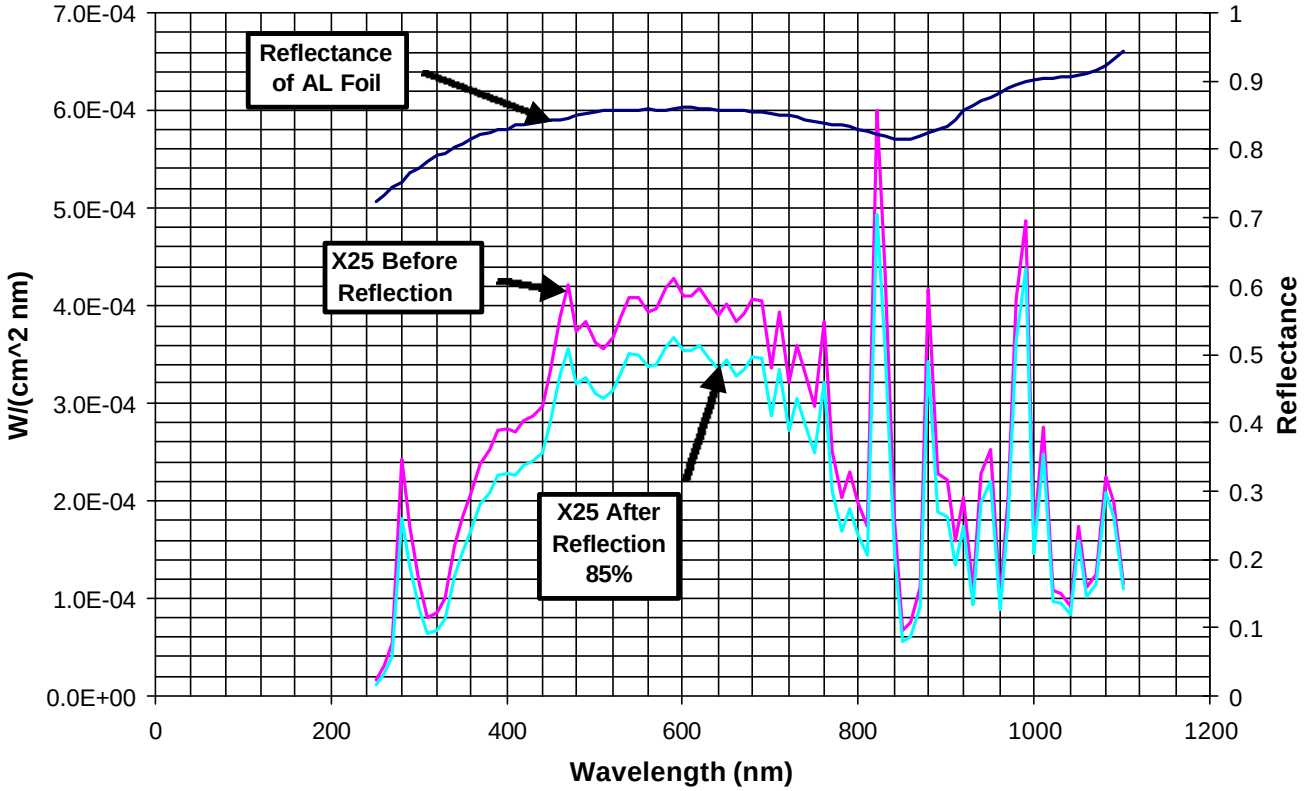
Chamber and Instrumentation

- **1 E-7 Torr Working Vacuum**
- **Clean Vibration Free Ion Pump**
- **View Ports for Exposing and Observing sample**
- **1 x 10^{-8} N Force Resolution**


X25
OUTPUT LENS
VACUUM CHAMBER
WINDOW


FORCE MEASURING DEVICE
TARGET
INCIDENT PHOTONS
MIRROR

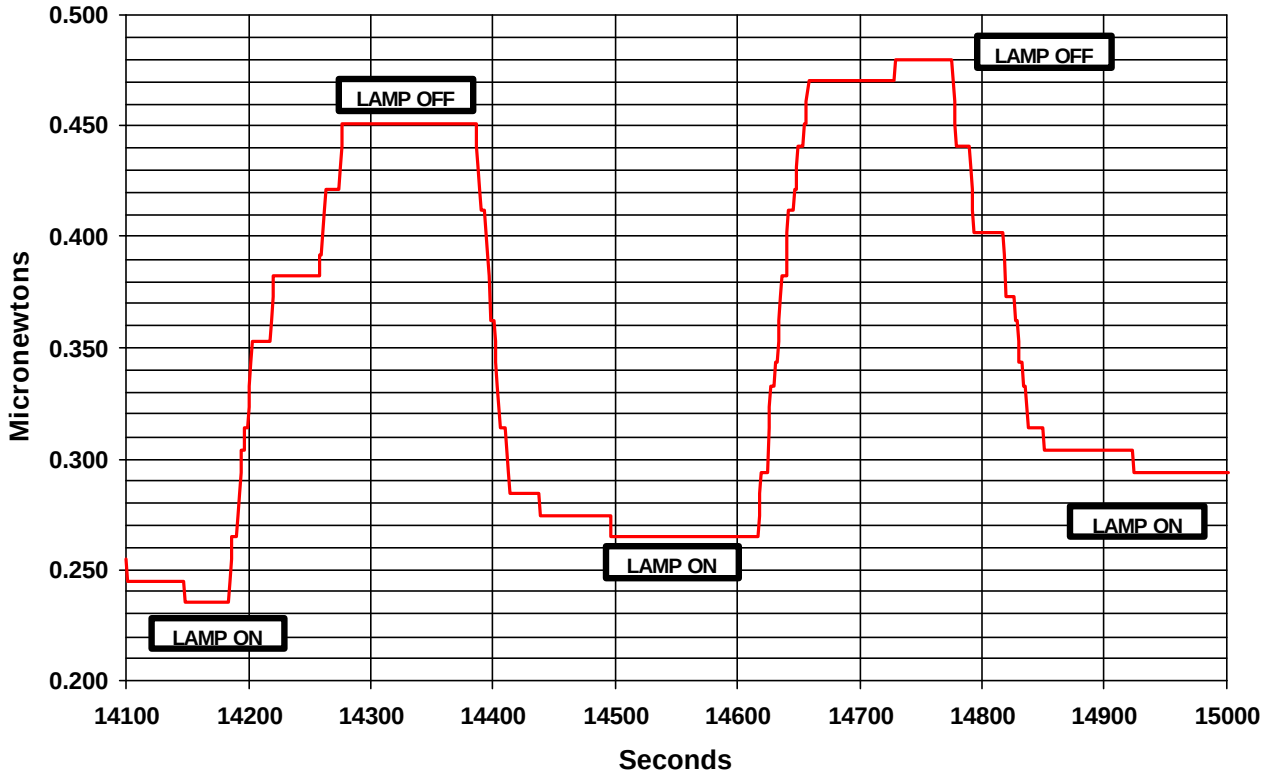
Sample Reflectance and X25 Spectrum Before and After Reflection



RESULTS

Sample #	Micro-Newtons	Percent
Average of 13 Data Points	0.217	93.5% of Calculated Force
Standard Dev.	0.016	7.4% of Average
Calculated Force	0.232	

PLOTTED PHOTON FORCE FROM TARGET

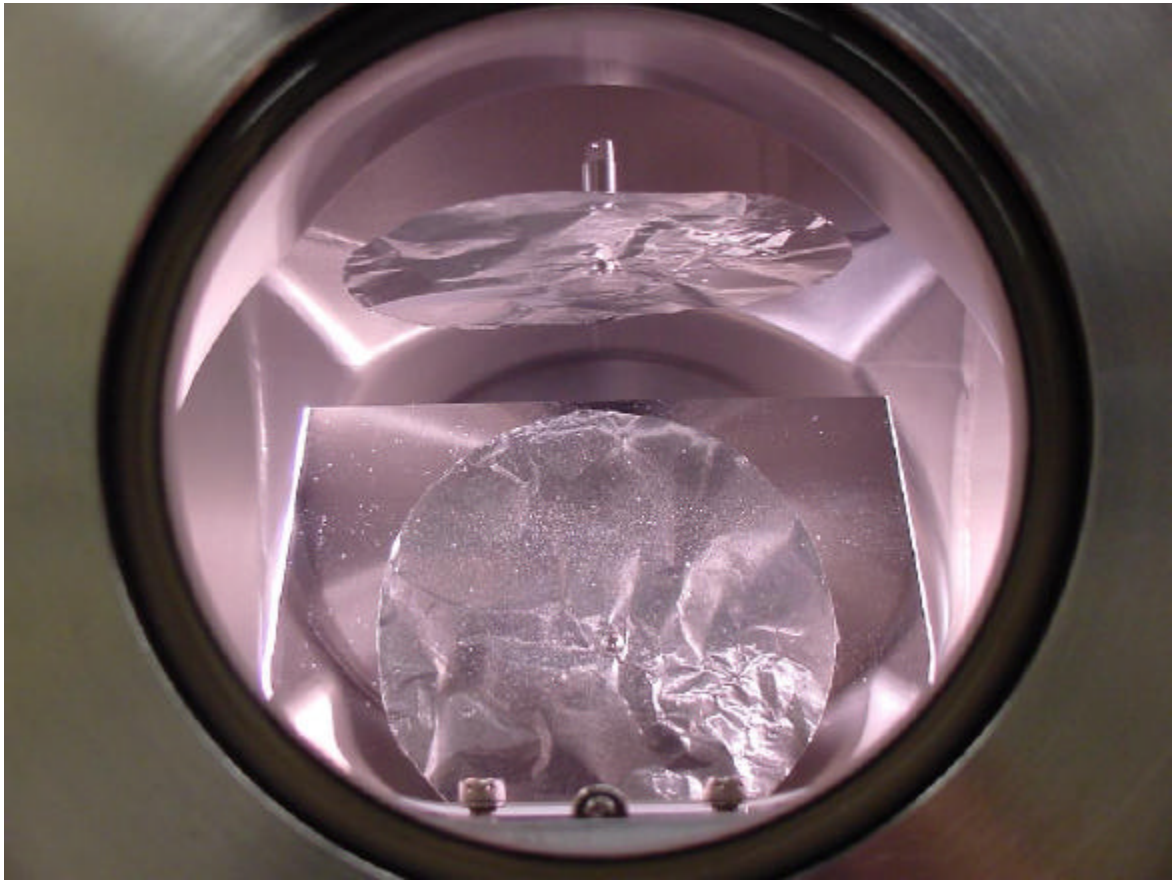


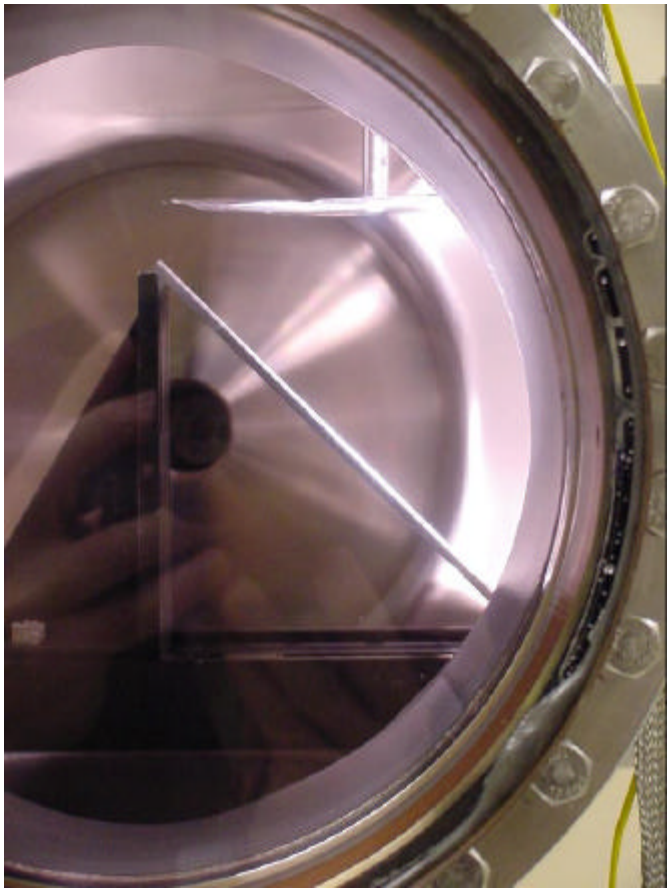
SUMMARY

- The Experimentally Determined Force on the Solar Sail Material Was Within 10% of the Calculated Value.
- Accurate Direct Photon Pressure Measurements Are Possible on Solar Sail Materials Under Full Spectrum Solar Simulation.
- Measurements Will Improve When the Sample Size Is Matched to the X25 Output Beam, When Radiometric Error Is Minimized, and When Third Order Effects Can Be Accounted For.

FUTURE

- **Use Real Sail Materials**
- **Optimize Sample Size to Fit X25 Beam Using New Chamber**
- **Improve Flux Measurements**
- **Quantify Scattered light**





MORE CALCULATIONS

$E^2 = m_0^2c^4 + p^2c^2$ $m_0=0$ **Special Relativity**

$E = pc$ or $p = E/c$, **Momentum, p, of an Object**

$p = Ft$ or $F = p/t$

$P = F/A = E/Act$

$I = E/At$

$P = I/c$